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VALUE OF THE PRELIMINARY STRESS IN SUSPENDED CONSTRUCTIONS,(U)
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by

S. A. Il'yasevich, N. S. Moskalev, S. S. Mkrchants

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Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

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VALUE OF THE PRELIMINARY STRESS IN SUSPENDED CONSTRUCTIONS.

Dr. of tech. sciences Prof. S. A. Il'yasevich, candidates of tech. sciences N. S. Moskalev, S. S. Mkrchants. USSR, CSRI [ЦНИИ - Central Scientific Research Institute] of the structures im. V. A. Kucherenko.

The specific special feature/peculiarities of suspended constructions, which include not only known by all valuable qualities of these systems, but also some shortcomings, require of the researchers of the comprehensive study of this form of constructions, beginning from material and ending with the whole systems. In this case, if we consider characteristic to usual suspended constructions kinematic variability, high value for them it acquires the preliminary stress, which raises the common/general/total rigidity of suspended systems.

In recent years in TsNIICK im. V. A. Kucherenko, were carried

cut the comprehensive experimental-theoretical investigations of the prestressed suspended constructions. They included the study of separate cell/elements, their junction/unit connections, and also the whole systems of the coatings, flat/plane and three-dimensional/space.

In report are given basic results of the conducted investigations. Is illuminated the work of large-diameter cables for alternating loads, the friction clamps, two-strip guy farm/trusses and some three-dimensional systems with static loads (radially guy, combined and others). Furthermore, it is considered the role preliminary stress in suspended roofs as during installation, so also in operation, of the making it possible to create in the process of installation the specific intermediate static systems with directedly adjustable effort/forces.

The investigations of the prestressed suspended constructions were initiated in TsNIISK im. V. A. Kucherenko from the study of mechanical properties of cables with static and cyclic loads. Investigations were conducted on large-diameter cables to unique suspension bridges and transfer/transitions, namely: the cables of bridge Erzhebetin g. Budapest, bridge through harbor in main Kiev and a bridge-transfer/transition of the gas pipe through Amu-Dar'ya River.

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The testing by static load underwent the channels of the open and closed coiling of different diameters from 38 to 70 mm. The specimen/samples of cords were flooded in the end sleeves with the aid of the alloy of TsAM. First cords they inspected with the aid of extensometric instruments for purpose of determination of their elastic and inelastic drawing, modulus of elasticity, compression of diameter, creep of alloy in bushings. Load in this case did not exceed 0.5-0.6 from breaking strength. Then cords subjected to extension to the rupture point. The basic results of static tests following:

1) Aggregate strength somewhat exceeds standard, which is explained by the fact that the strength of wires is understated in comparison with real;

2) destruction did not occur near bushings or because of extraction from bushings. This speaks about sufficient strength of anchor equipment/devices and alloy of TsAM;

3) locked ropes had a modulus of deformation lower than

calculated. In certain cases the modulus of elasticity was stabilized only after 50 cycles of loading.

In the second stage were conducted the testings by cyclic load.

In all were tested 26 samples of locked ropes 54.5 mm and 8 specimen/samples in diameter of suspensions made of the cables of spiral coiling 64.5 mm in diameter for a bridge Erzhebet. Testings were conducted in the machine "Amsler", establish/installed into NIS of hydroelectric power project, which reproduced load with the frequency of 250 cycles per minute.

The specimen/samples of closed type cords tested under medium load 80 t with the amplitude of oscillations ±10 t. Suspensions tested on special wheel 800 mm in diameter, around which they were bent, forming two branches. Load on suspensions was 140-110 t ±15 t in amplitude,

In the process of testings, they were carried out tensile measurements the strains of cords, and also was record/fixed the gap of individual wires as a result of fatigue.

Most interesting the following results:

1. First 10 samples of locked ropes showed relatively low durability. The breaks of wires began already after 300 with thousand cycles, and toward the end of the testing in 2 million cycles in cords were counted to 10-12 breaks of wire.

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Breaks they occurred mainly near bushing. The basic reason for low fatigue strength was incorrect technology of alloy pouring, with which bushing was not preheated. Furthermore, hurbenium itself, initially used, render/showed unsuccessful.

2. Passage to alloy TsAM and system of pouring bushing , accepted in Soviet Union, noticeably raised quality of specimen/samples. The breaks of wires in cords became more rarely, occurred they at a distance from bushings, but 4 cords not at all had breaks for always of testing - 2 million cycles.

3. Modulus of elasticity of cords when were not breaks of wire, always retained its constant value ($1.66-1.70 \cdot 10^6$ kg/cm^2).

4. Conditional fatigue limit for this load conditions was 55-48 kg/cm^2.

5. Reduction of specimen/samples by transverse load, produced for purpose of imitation of transmission by cords of transverse pressure on supporting assembly, led to sharp reduction/descent in service life and fatigue strength. So, transverse reduction by the force of 100 t for the participation of specimen/sample 80 cm in length, the caused specific lateral contraction of cord 230 kg/cm², led to the complete destruction of cords long before 2 million cycles. In this case, all the destruction of wires occurred on the boundary between the squeezed and unreduced sections of cord. And this despite the fact that the reducing equipment/device provided the uniform application/appendix of reduction and smooth transition to the unreduced section. The conditional limit of fatigue of four specimen/samples, which had reduction, did not exceed 43 kg/cm².

6. Suspensions, prepared from multistrand cords 64.5 mm in diameter and tested by those bent on wheel 800 mm in diameter with peak load 140 t, obtained breaks mainly on bent, bent section, which fit closely to wheel. In 2 million cycles occurred on 12-14 breaks of specimen/sample with maximum voltage 23.2 kg/cm² (referred to entire section/cut on the average).

Investigations reveal/detect/exposed the same range of light coatings, the fluctuations of the stresses in which can be caused by wind impulsive load and in which are possible fatigue effects.

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Then were carried out testings of junction/unit connections in connection with cable constructions.

The purpose of the work was the development of the assemblies of cable farm/truss and checking their reliability. The formulation of the problem was caused by the fact that to the assemblies of cable farm/trusses with unbalanced loads affect the large in value shearing forces. But for of perceiving them, it is necessary to ensure sufficient communication/connection between the assemblies and the stressed cable. But since this communication/connection depends not only on the amount of force, which clamps cable in connection but also from the coefficient of friction between them, or inasmuch as with an increase in the transverse reduction by cable by clamp grow/rises the danger of its break in clamp with alternating loads, as this was shown in the preceding/previous testings of separate cables, in assigned mission was natural search for the largest possible increase in the resisting forces to the shift/shear between clamps and cables under the minimum reducing force. Tests were carried out with lamellar clamps 120 mm in long, made from steel of brands St.3 and St.45 with smooth and corrugated internal surface on

the cables of spiral communication/connection with a diameter of 31.5; 38.45 mm, and also stranded cable. The shift/shear of clamps was realize/accomplished by hydraulic jacks, stress force by a bolt-dynamometric key/wrench.

As a result it was revealed, that the diameter of cable, the form of coiling, the trademark of steel of clamp (its hardness) do not have noticeable effect on the value of the coefficient of friction. Testings showed the sufficiently significant magnitude of an incidence/drop in the frictional forces with the elongation of cable with an increase in it of the effort/force. to avoid this is possible raising compression of cable or increasing the coefficient of friction. As it was noted above, the strong reduction of cable is undesirable.

For an increase in the frictional forces the surface of the part of the clamps, which adjoins the cable, it was made corrugated, that, however, did not give the effective results. Another part of the clamps was made with frictional linings, lead and bilateral emery. It was establish/installed that the application/use of lead packing also is barely effective. Emery packing lead to an increase of the coefficient of conditional friction 2.5 times in comparison with smooth steel, i.e., $k_{тр} = \frac{T_{ср}}{\Sigma_0}$ to 0.66. (Here $T_{ср}$ and Σ_0 - respectively shearing force and total stress force of the bolts of

clamp). These linings are simple, convenient and can be recommended for time/temporary type constructions.

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An even larger effect was obtained during plotting on the contact surfaces of epoxy glues, especially during the use as filler of corundum or quartz sand (last/latter true, somewhat less was effective). Such clamps maintain/withstood shearing forces 5.5 times greater than without glue.

Following development and investigation of separate cell/elements and elements of suspended constructions carried out the studies of the whole systems both of planes and three-dimensional/space, including theoretical developments, and also testings of large-size models.

One Of the purposes of the test was the investigation of the role of the preliminary stress of suspended systems, possibility of the regulating of the stresses in carriers. The preliminary stress in suspended systems makes it possible to bring together and for the minimum kinematic displacement/movements, i.e., to considerably decrease main disadvantage in the flexible constructions. Their second designation/purpose is a reduction/descent in the amplitude of

the oscillation/vibrations of the stresses, caused by time/temporary load. The amplitude of the oscillation/vibration of stresses A, for example in string, is determined from dependence $A=\frac{\Delta P}{P}K\sqrt{\frac{1}{1-\rho}}$ where K - parametric coefficient; ρ - ratio of preliminary stress of string to calculated; ΔP - the frequently repeated load, which leads to fatigue; P - calculated static load.

The correctly assigned one multistage preliminary stress makes it possible to make constructions of coatings more light/lung and simultaneously raises their durability and service life.

First was studied circular into panel model as frameworks of which served the two-flange radially arranged/located flat/plane systems (but in figure), attached on external carrier ring and intersecting in center. Different combinations of loads caused in the system of effort/force and strain, on the whole the well confirmed calculation formulas. Interesting was the study of the effect of the preliminary stress with increase in which the kinematic displacement/movements of suspended system were decreased. Variations with the flexural rigidity of ring showed that this rigidity can be considerably decreased, since prestressing realize/accomplished in two-flange systems, leads to the fact that they themselves possess high resistivity during a change in the distance between supports and, therefore, will redistribute well loads without the noticeable

strains of carrier ring.

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By the increase of prestressings it was possible to noticeably raise the stability of coating, and also the stability of index contour, which made it possible to utilize for it high-strength steel and a simple tubular section/cut.

Then it was carried out study of the real work of the prestressed guy farm/trusses with upper carrying belt and vertical suspensions for purpose of compilation on the basis of the conducted investigation of recommendations regarding calculation and construction of data construction.

Basic partly of these investigations was testing for static load of two versions of the large-size models of guy farm/trusses flight/spans on 30 m, which were differing the from each other by construction of the neutral assembly (see b on figure).

Testing farm/trusses was carried out for load 1000 kg/ running meter, In intensity m, applied by separate stages on 0.3-0.6 t and according to fifteen different patterns, including the evenly distributed on entire flight/span and one-way of load, and also

concentrated and different combinations of them.

Are most interesting the following results:

1. The connection of belt/zones at midpoint, which impedes their mutual horizontal displacement, noticeably raises the rigidity of guy farm/trusses with unsymmetric load. So, with one-way load by time/temporary distributed load for the farm/truss of the first version (with the disconnected belt/zones) vertical displacement/movements exceed similar values for the second version, with the connected belt/zones.

2. Analysis of graphs of vertical sagging/deflections of farm/trusses from action of concentrated forces showed real possibility of this load. But in this case in order to avoid the introduction of the supplementary distributing struts, it is expedient to arrange/locate these forces on those sections of the farm/trusses where they cause the smallest sagging/deflections. In the farm/truss of the first version, such sections are arrange/located in the middle flight/span, else, near supports. In the farm/truss of the second version - in the thirds of flight/span, it is nearer to supports.

3. Comparison of experimental and thecretical values in essence ccnfirmed correctness of prccedure cf calculatien of two-flange guy farm/trusses accepted, which was with us reccmmended for further use in designed practice.

4. Testings showed alsc reliability of structural solutions of assemblies of guy farm/trusses accepted, develcped and investigated earlier.

5. Preliminary stress of syste= significantly decreased kirematic displacement/=ovements with unbalanced loads, in particular for version with disconnected belt/zcnes.

Thus, together with the ccnnectien of assemblies appears possibility to achieve stability by the increase of variable vcltages.

The second the studied syste= was a cable-girder orthogonal grid (a in figure). Such systems can be used in the coatings of rectangular plan/layout. Filaments will bear their load, the cross beams are distributors. Furthermore, the ends cf the beams are fastened on supports so that in the= can appear the negative vertical

reaction. If the ends of the beams are tightened and to their supports, then because of the flexural rigidity of beams it is possible preliminarily to strain entire system.

Prestressed cable- girder network render/showed very rigid, strains in comparison with the freely hanging filaments decreased several times. Coating render/showed suitable for organizing the light/lung suspension transport. From the unsymmetric relative to the filaments of loading effective stabilizer render/showed the transverse horizontal farm/truss, formed of two adjacent beams of the systems of those connected by grid/cascade. This farm/truss decreases horizontal displacement of filaments to the side of load. The shear forces of farm/[truss] transfers to vertical communication/connections, arrange/located in the plane of supports.

Cable- girder systems possess a series of the advantages main from which - rigidity and simplicity of performance. In our opinion, such systems must find their place in building.

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The third system which was studied, "Gipar"- a coating in the form of hyperbolic paraboloid on square plan/layout. From the usual draw strings of "Gipar" it differed, by the fact that instead of

[paired ?] convex filaments us were suggested the flexible arches, capable of working on compression (e in figure). As a result in the index contcur of this systen, do nct appear the bending moments from full lcad. It is real/actual, guy is drawn cut cutline/contour inside building, but this impede arches. Furthermcre, arches, possessing flexural rigidity, are the stabilizer cf systen. On model was studied the deformation of system, and alsc the ability of the flexible arches, fastened with filaments, tc retain stability. System turned cut to be very light/lung, rigid. Arches favorably to make rare, after concentrating rigidity in the smaller number of cell/elements. rigidity render/showed highly useful, alsc, in cutline/contour, since increased the adaptability cf system, the stability of very arches of coating. The regulating of stresses, accomplished by the stretching cf filaments, made it possible to raise the stability of arches.

The following studied pattern was crucifors filament-arc coating. System represents by itself two diagonally directed arches with those suspend/hung tc them alcng perimeter by threads (f in figure). Ccnstructbion was obtained by outwardly braceless, needing vertical supports only the angles cf the overlapped location. In this case, the coating can have almost any planfcrm, have any quantity of salient angles. Model for the study of system was made square, since this fcrm best corresponds to real buildings. Since the arches, running, a total of two, they are obtained powerful, which

facilitates the problem of imparting to them the stability. The filaments which serve as if tightenings of arches, themselves form entire expanded surface of coating.

In cruciform system were investigated mainly the stability of arched cross pieces and their deformation, bending from plane with nonuniform loading.

System showed itself very light/lung and durable, suitable to the overlap of the largest flight/spans, and at the same time, as it is interesting to note that making it possible to have pure/clean space on entire perimeter.

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Cross pieces are best to develop in vertical plane in order to increase the resistivity of arches with noneguilibrium load. In order to ensure the stability of arches from plane, it is better/best in all as filaments to use preliminarily stressed high-strength steel strings. By the way, this prestressing will free from the need for giving to system any supplementary form of stabilization.

The regulating of the stresses was realized in the cross membrane/diaphragm-arched coating of pavilion with size/dimensions

30x30 m, erected in the athletics ground of the stadium of "Dynamo" in Moscow. The tension of sheet diaphragm/membrane along the diagonally arranged/located arches made possible to include/connect the significant part of the section/cut of diaphragm/membrane in the work of arches not only for elongation, but also for compression of the bending, appearing in arch from one-way load.

At this cruciform system has variety with support in center. The special feature/peculiarity of this variety was new possibility to have a building, standing on one point in which unlike tent or umbrella of construction along perimeter they are arrange/located at maximum altitude, which is profitable, for example, during building of hangars, hot-houses, commercial centers, etc.

Following from the studied systems were rationally guying systems (ж in figure), making it possible completely eliminate from flight/span compression members, also, at the same time have rectilinear moment-less index contour. In this system, similar to tent coating, easily it is organized drain. System makes it possible to have a support to fours and even to two points in angles. In these systems was studied the kinematic strain of circuit elements, forming in plan/layout square, the transformation of square into rhomb and parameters of filaments and tightening, ensuring minimum "rhombizing" of supporting/reference square.

On the figure (see 3) is shown one additional new pattern of suspended coverings, investigated in TsNIISK im. V. A. Kucherenko. These are the combined outwardly braceless system on square plan/layout, used Lenpromstroyproyekt in the project of the coating of the main commercial hall of Krasnoyarsk market with size/dimension 42x42 m. The span construction of this coating consists of the combination of five radial guying systems - by one central and four angular, divided by the flat/plane carrier ring, inscribed into the plan/layout of the overlapped area.

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For purpose of the development of recommendations regarding the planning of the coating indicated in institute, were carried out the comprehensive studies of the new system, including a whole series of the problems main of which consisted of following:

1) the study of the real work of new system during a change in its design diagram, and also the separate cell/elements at the stage of installation and operation (study "purely" guy system with the packed plate/slabs, but also the single shell, formed after packing of plate/slabs and monolithization of interplate welds);

2) the development of the procedure of calculation of coating and its cell/elements at different stages;

3) the development of the method of the formation of the monolithic shell of the increased rigidity.

The conducted investigation included the theoretical and experimental part and was accomplished on large-size model.

Were obtained the following results:

1. Is developed the sufficiently simple procedure of calculation of coating at different stages of its work. Simplification in the calculation is realized because of the separation of coating according to structural/design sign/criterion to the calculation of central and angular parts taking into account their mutual effect. The obtained experimental data confirmed in essence the design considerations accepted.

2. Is revealed advisability of transforming guying system into monolithic suspended shell when substantially decreased deformation of system, and was noted discharging carrier ring.

3. Is revealed advisability of inclusion into joint operation with guy system of flooring slabs, for which it is necessary to ensure appropriate reinforcement of shell. Furthermore, is made an also whole series of structural/design recommendations (equipment/device of supplementary supports for a ring in the places of its contact with on-board cell/elements, construction of the coupling of different parts of the shells, etc.).

4. For preservation of shell from its cracks it is necessary to make that prestressed. In institute it was developed and it is experimentally tested one of the possible methods of prestressing of the shells, having the surfaces of the negative Gaussian curvature ensuring their solidity and the increased rigidity with different loads.

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Recently in institute, it is developed and now is investigated also a whole series of the new prestressed guy systems whose large part is fulfilled on rectangular plan/layout. For example, the system where the spacing forces from guy farm/trusses are not caused the high bending moments in the rectilinear cell/elements of index

contour because of the inclusion intc the work cf the supplementary stiffening joints, working together with guy-sets or curvilinear and flex-less with the basic fcrm cf lcading by the cell/elements which receive in essence the thrust cf guy farm/trusses (Fig. 1i, j).

All patterns as a whcle ccnsiderably expand the field of application of light/lurg suspended rocves, they make it possible by ccmparatively simple resources to cverlap very significant flight/spans and to successfully ccmpete with traditional coatings with the usual flight/spans of indtstrial ard civil buildings.

As a result of investigations, were ccmprised the reccmmendaticns regarding ccnstructicn and calculation of different cell/elements and systems cf the prestressed guy constructions, which must contribute to the even more wide applicatcn of these pregressive forms of ccnstructicns.

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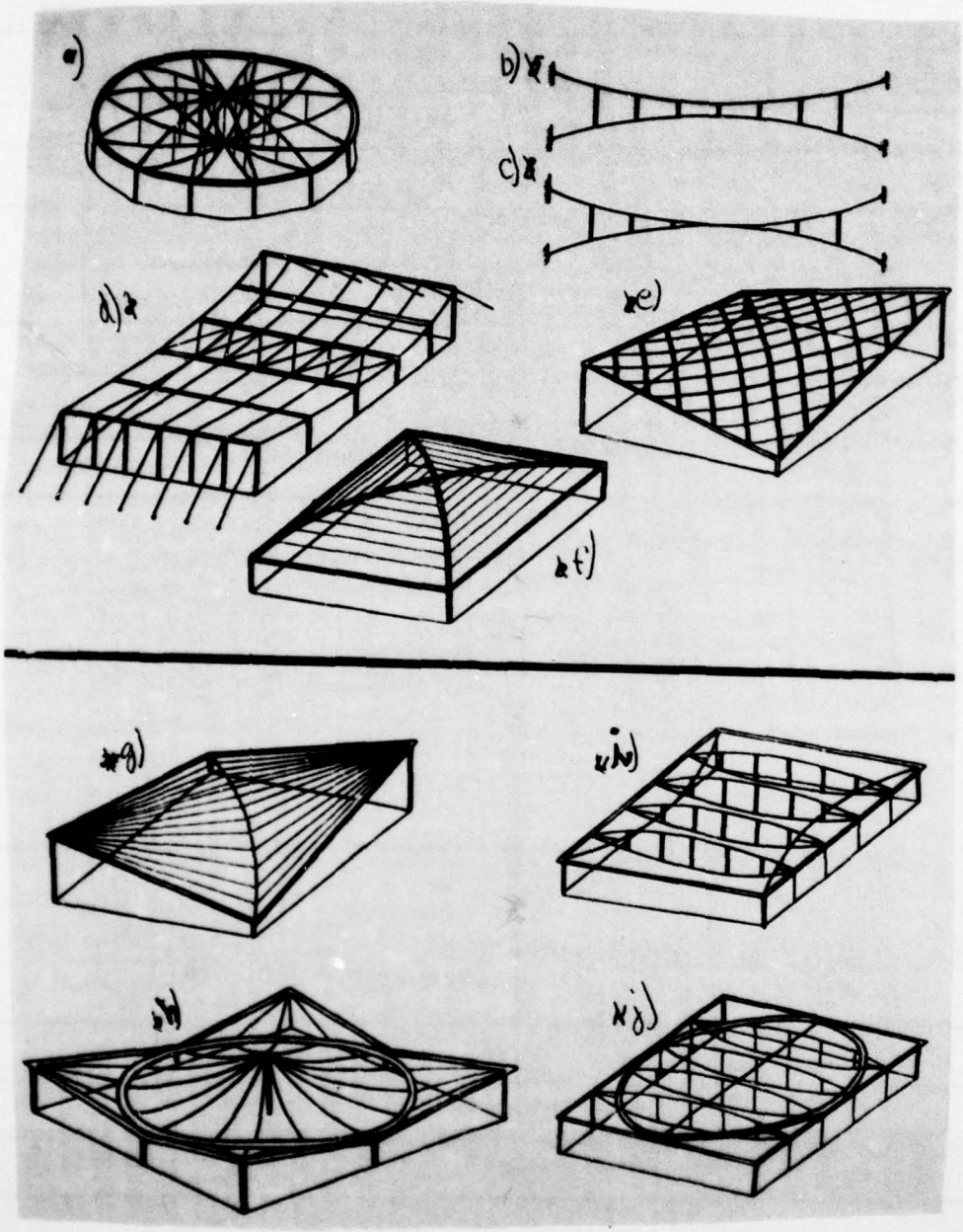

The patterns of some types of the prestressed suspended rooves.

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